Frontera Space Emergency Procedure: Liquid Pool/ Spill Formation

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1 PURPOSE

This procedure defines required actions for response to liquid hypergolic propellant spills, including formation of surface pools of MMH, MON-3/N_2O_4, or associated byproducts.
The objectives are to protect personnel, control vapor generation, prevent ignition or escalation, and ensure compliant emergency notification.

2 SCOPE

This procedure applies to:

- Any liquid fuel or oxidizer release on or around the PTSD stand
- Any wetting of ground surfaces, hardware, structures, or containment
- Any spill resulting from test article failure, line rupture, valve malfunction, or purge event
- Normal operations, post-test phases, and post-incident recovery

This procedure covers both contained pools (sumps, pads, trenches) and uncontained surface spreads.

3 TRIGGERING CONDITIONS

This procedure is initiated when any of the following occur:

- Visible pooling or liquid accumulation beneath tanks, lines, or test articles
- Sensor alarms or camera observation of wet surfaces
- Sudden depressurization or loss of contained fluid volume
- Personnel or cameras observe splashing, dripping, or running liquid
- Post-UER debris indicates leaking hardware

A spill shall be assumed hazardous and actively evaporating until verified otherwise.

4 IMMEDIATE CONTROL ROOM ACTIONS

Upon detection of a spill or pool:

- Announce “Liquid Spill — Evacuate the Stand.”
- Initiate Emergency Stop (E-Stop).

Safe the stand by:

- Closing isolation valves
- Halting all flow commands
- Inhibiting ignition or energized systems

- Confirm stand evacuation (if personnel were present).
- Freeze all nonessential operations.

No personnel shall approach the stand.

5 REMOTE ASSESSMENT

Using remote camera systems, sensors, and telemetry, the Control Room shall:

- Determine approximate spill location and pooling extent
- Identify product type (MMH, MON-3, mixed hypergolic residue)
- Assess whether spill is confined or uncontained
- Review weather data: wind direction, speed, temperature

All assessment shall remain remote-only.

6 VAPOR GENERATION & DISPERSION RISK

Because liquid pools of MMH or MON-3 actively generate vapors, the following must be assumed:

- N_2O_4 pools dissociate to NO_2, creating visible brown vapor clouds
- MMH pools produce toxic vapors even at low temperatures
- Pool evaporation may persist for hours to days depending on surface area
- Use the site ALOHA dispersion analysis to evaluate possible downwind impact.

If harmful vapors *may* cross the property boundary → proceed to Emergency Notification.

7 FALSE-POSITIVE SPILL VALIDATION

If a spill is suspected but all fixed-area toxic-gas detectors remain at 0.0 ppm, the event shall be treated as a potential false positive until validated. Emergency services shall be immediately notified of confirmed releases. If the release has not been confirmed, inform emergency services of release and of possibility of false positive and time to complete verification.

All validation actions must maintain a conservative safety posture.

1. Remote Verification

The Control Room shall first attempt to validate or rule out a spill using remote systems:

- Review camera feeds for liquid pooling, wetting, discoloration, or visible vapor.
- Check system telemetry for pressure drops, valve faults, or abnormal flows.
- Evaluate fixed detector history for intermittent or transient readings.

- Confirm no signs of vapor plume formation (e.g., brown NO_2 for N_2O_4).

If remote verification cannot confidently eliminate the possibility of a spill, proceed to controlled in-person validation.

2. SCAPE Upwind Approach

With Safety Officer authorization, a SCAPE-suited technician may approach the stand from the upwind direction only to verify conditions with a calibrated portable toxic-gas detector.

The technician shall:

- Advance cautiously to the minimum distance needed to obtain readings.
- Inspect for local wetting, drips, or vapor evolution not visible on cameras.
- Record detector readings throughout the approach.

If the portable detector remains at 0.0 ppm, no spill indicators are observed, and no vapors are detected upwind, the technician shall withdraw and proceed to fence-line verification as needed.

3. Downwind Fence-Line Verification

If uncertainty persists—particularly regarding off-site migration potential—a SCAPE-suited technician may walk the inner downwind fence line to confirm:

- No vapor movement beyond the property
- Detector readings remain at 0.0 ppm
- No discoloration, plume formation, or surface wetting outside the test stand

This activity is verification only; no corrective actions are permitted during the walk.

4. Clearance or Escalation

A suspected spill may be classified as a false positive if:

- All fixed detectors read 0.0 ppm
- Portable detectors read 0.0 ppm during upwind and fence-line checks
- Camera and telemetry review reveal no spill or vapor indicators
- The Safety Officer confirms all observations and authorizes clearance

If at any point readings exceed 0.0 ppm or physical evidence of a spill is observed:

- The event becomes a confirmed spill, and
- The procedure immediately transitions to Liquid Spill / Pool Formation response steps, including emergency notification.

If you want, I can integrate this directly into your full Liquid Spill / Pool Formation procedure as Section 7.x or provide a renumbered complete document.

8 EMERGENCY NOTIFICATION & TIER II / LEPC REQUIREMENTS

If the spill produces vapors with potential off-site impact:

- Call 911 immediately for awareness and standby support
- Notify the Local Emergency Planning Committee (LEPC) and Fire Marshal per EPCRA Tier II requirements
- Provide responders:
- Chemical(s) involved
- Estimated spill size
- Wind direction and hazard path
- Stand status and evacuation posture

Notifications shall occur early — not after confirmation.

9 EXCLUSION ZONES

All personnel shall remain upwind only.

- The downwind corridor becomes an Immediate Hazard Zone.
- No re-entry is permitted until authorized by the Safety Officer.

If safety systems are operational and vapors appear contained, a SCAPE-suited technician may be authorized to:

- Walk the inner fence line only
- Verify whether vapors are exiting the property
- Use calibrated portable detectors
- No corrective action shall be attempted during this walk.

10 SPILL STABILIZATION (REMOTE ACTIONS ONLY)

The following may be used to reduce vapor production only if approved by the Safety Officer:

- N_2 passivation to inert tanks and lines feeding the spill
- Controlled drainage, if containment is designed for it
- Isolation of leaking systems via remote valves
- Exposure minimization by limiting airflow toward the pool
- No water or incompatible medium shall be applied to hypergolic spills.
- IPA flushing is prohibited unless the leak source is isolated and ignition risk eliminated.

11 PASSIVATION OF MMH POOLS USING BLEACH

MMH pools shall not be allowed to dissipate naturally.
Unlike N_2O_4, MMH does not readily evaporate and must be chemically neutralized once the spill is stabilized and isolated.
All MMH neutralization operations shall be performed only under SCAPE and only after the Safety Officer authorizes entry.

1. Preconditions for Neutralization

Bleach neutralization may begin only when:

- The spill source is isolated and flow is stopped
- No ignition or thermal hazard exists
- Vapors have been assessed and are stable
- The stand is in a confirmed safed and evacuated state
- A SCAPE-suited team is assembled and equipped with calibrated toxic-gas detectors
- Bleach shall never be applied near N_2O_4 spills due to hazardous chlorine reactions.

2. Approved Neutralizing Agent

The approved neutralizer for MMH pools is:

- Sodium hypochlorite (NaOCl) solution, 5–10% available chlorine
  (standard fresh household bleach is typically 5–6%)
- Supplemental neutralizers (if required):
- Calcium hypochlorite (solid granules)
- Hydrogen peroxide (10–30%) for materials incompatible with hypochlorite

3. Neutralization Procedure (SCAPE Required)

Step 1 — Approach

- SCAPE technician approaches from upwind only
- Portable detector is used continuously to track MMH vapor levels
- Technician maintains communication with the Control Room and Safety Officer

Step 2 — Initial Application

- Apply sodium hypochlorite slowly and in controlled amounts to the edge of the pool
- Allow neutralizer to wick inward to avoid a rapid exothermic reaction
- Observe for:
- Heat generation
- Bubbling or fizzing
- Color changes in the liquid
- Reduction in MMH vapor levels

- Reaction products may include hydrazine chloramines; SCAPE is mandatory.

Step 3 — Full Application

- Continue adding bleach until the entire surface area and volume are contacted
- Ensure complete wetting of porous or textured surfaces
- Maintain distance; avoid disturbing the pool with splashing or agitation

Step 4 — Confirmation of Neutralization

- Neutralization is considered complete when:
- Portable detector reads 0.0 ppm MMH above and around the treated pool
- No additional vapor is detected while slowly stepping back
- Reaction activity has ceased (no bubbling, heat, or odor)

Step 5 — Water Dilution (Final Step)

- Once reaction is complete:
- Apply a light, controlled water spray (NOT a hose stream)

Purpose:

- Complete reaction
- Reduce concentration of residues
- Dissolve and remove chlorinated byproducts
- All rinse water shall be treated as contaminated waste.

4. Post-Neutralization Requirements

- After neutralization:
- Area remains restricted until Safety Officer clears it
- Surfaces are inspected for trapped residue
- Hardware or debris wetted by the spill is collected and moved to the PTSD bakeout oven for full passivation
- Detector readings must remain 0.0 ppm before down-posting SCAPE
- All steps must be recorded as part of the spill documentation.

5. Critical Safety Notes

- Never mix bleach and oxidizer (N_2O_4) contamination
- Never use bleach if the spilled chemical cannot be clearly identified as MMH
- Apply bleach in small incremental amounts to avoid violent reaction
- MMH neutralization shall never be attempted without SCAPE
- All neutralized material and rinse water are hazardous waste

12 TRANSITION TO SAFE STATE

A spill event is considered stabilized only when:

- Vapor concentrations return toward 0.0 ppm
- Pool is no longer increasing in size
- Spill supply is isolated and depressurized
- Safety Officer confirms all systems are in a passivated condition
- Downwind hazard has dissipated based on detector readings and ALOHA modeling

13 SPILL RECOVERY & CONTAMINATED HARDWARE HANDLING

After stabilization:

- All wetted surfaces, hardware, and debris shall be treated as contaminated
- Recovery teams shall operate in SCAPE until cleared
- Recoverable hardware shall be collected, contained, and transferred to the PTSD bakeout oven
- Hardware and debris remain contaminated until detectors read 0.0 ppm after bakeout

Ground surface contamination will be evaluated by Safety Officer for neutralization, removal, or controlled drying.

14 DOCUMENTATION & REPORTING

The following shall be recorded:

- Spill volume estimate and pooling behavior
- Vapors observed and detector readings
- Dispersion modeling assumptions
- Emergency notifications made (911, LEPC, Fire Marshal)
- Stand configuration and stabilization actions
- Hardware collected for passivation
- Final clearance authorization by the Safety Officer
- A formal incident report is required within 24 hours.

15 RETURN-TO-OPERATIONS AUTHORIZATION

Operations may resume only when:

- Spill is mitigated and vapors have dissipated
- Stand is purged, isolated, and confirmed safe

- All contaminated hardware has been removed and controlled
- Environmental and safety monitoring show 0.0 ppm
- Safety Officer grants clearance
- Test Director issues return-to-operations authorization

16 PROGRAM MAINTENANCE

This procedure shall be:

- Reviewed annually
- Updated following any vapor release event
- Revised upon system, hazard, or regulatory changes